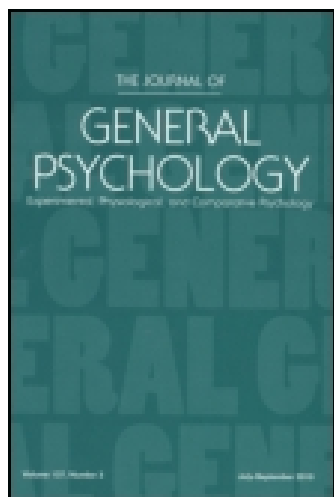


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THE REINFORCING EFFECT OF A DIFFERENTIATING STIMULUS*

From the Biological Laboratories, Harvard University

B. F. SKINNER¹

The present paper continues a series in which the investigation of a selected example of behavior has been reported. The example is a chain of reflexes constructed in the following way. (S^I-R^I) is a reflex of long standing in the history of the organism, in which the stimulus S^I is composed of any or all of the energies arising from a bit of food and the response R^I is the seizing of the food. Subsequent members of the chain (which bring about the ingestion of the food) do not concern us. A preceding member is attached as follows:

$$S^{II}-R^{II} \rightarrow S^I-R^I,$$

where S^{II} is the stimulation supplied by a food tray and R^{II} is the approach to the tray in any way that will bring S^I into action. A third member could be attached by allowing its response to produce the whole of S^{II} . In the present case a discrimination (2) is first set up, so that R^{II} is evoked only in the presence of a differentiating property or component. This is done by reinforcing R^{II} only when S^{II} includes the sound of a food magazine (D). Another member is then added by allowing its response to produce D alone. In the present case the third member is the pressing downward of a small lever. The chain then stands

$$S^{III}-R^{III} \rightarrow \underset{D}{S^{II}}-R^{II} \rightarrow S^I-R^I$$

where S^{III} is the stimulation supplied by the lever, R^{III} is pressing the lever, and where the first arrow is understood to connect R^{III} with D only.

The present paper is concerned with adding another member to this chain. Its purpose is not to see how far chaining may be carried

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out, but to observe the rate at which the new member is added. When ($S^{III}-R^{III}$) is conditioned there are several disturbing factors present, chiefly incidental effects of the new lever, which make its study difficult (1, 3). It is possible to avoid some of these in attaching a fourth member by using the same kind of response and especially by using the relatively stable method of periodic reconditioning (2).

A discrimination is first established by reinforcing every response in a stimulus complex which includes the lever and a differentiating stimulus L and by extinguishing all other responses to the lever in the absence of L (2, 5, 7). It is then necessary to set up a situation in which some arbitrarily chosen response will lead to the presentation of L , after which the discriminative response to the lever plus L ($S_{AB...L...}$) is immediately reinforced. This could be done by putting another lever in the experimental box or by using some other kind of response, but the result for another lever would be unclear because of induction (5, 6), and it would be hard to obtain any response that was different enough to be certainly free of this complication. The present procedure has been to use the *same* reflex. The experiment thus represents only one case—that in which the interference between reflexes III and IV will be maximal. A first response to the lever produces L ; a second response in the presence of L produces the sound of the magazine; and the response to the tray plus the sound of the magazine leads to food. The chain may be written

$$S_{AB...}^{IV} - R^{IV} \rightarrow S_{AB...L...}^{III} - R^{III} \rightarrow S_D^{II} - R^{II} \rightarrow S^I - R^I$$

The following method, which utilizes the relatively stable state of the rat under periodic reconditioning and can best be described by turning to an actual experiment. A group of twelve white rats, from which seven complete series were obtained,² approximately 140 days

²In view of the delicacy of this method we are not justified in assuming the irrelevance of even slight technical variations, and it is therefore difficult to bring a perfect series to completion. In the present case three series were eliminated when the differentiating stimulus was accidentally left on continuously for a few minutes during the first day of the discrimination. In one other case L remained absent during the last day of the discrimination because of a fault in the apparatus, and the rate returned to that characteristic of periodic reconditioning. The records in these four

old at the beginning of the experiment, were put on the usual schedule of daily experimental periods of one hour each, during which responses to the lever were reinforced every five minutes (for this method see 2). All the rats assumed an approximately constant rate of responding, in agreement with previous work. After two days of periodic reconditioning a discrimination was begun by sounding a buzzer (as the differentiating stimulus) whenever the next response was to be reinforced. After four daily hours the rate of responding in the absence of the buzz had fallen to less than half its original value. On the next day the order of events was as follows. When the rat was released, the buzzer was off. The first response turned it on and at the same time completed the circuit to the food magazine, making it ready for the next response. The second response, in the presence of the buzz, was followed by a discharge of a pellet of food into a tray where it was accessible to the rat. The buzzer was then turned off and the magazine disconnected. Responses during the next five minutes were ineffective. At the end of five minutes the apparatus was again set (without supplying any stimulus to the rat) so that the next response turned on the buzzer and the next after that discharged a pellet of food. The light and magazine were then turned off again. This was repeated at five-minute intervals during the hour. All responses to the lever were recorded.

After the discrimination had been begun, all the responses to the lever which produced food were in the presence of the buzz. Any inductive effect upon the responses in silence was weak or lacking. The responses still observed during the intervals in silence were, according to previous work, due largely to the original periodic reconditioning (2, 5, 7). These should have continued to disappear as the discrimination curve was carried out if the newly arranged correlation of one response every five minutes with the production of the buzz were having no effect. The experimental result, however, is that immediately upon changing to the new condition the rate of responding in silence increases until the original rate is reached, or at least approximately.

series are entirely compatible with the present conclusion but cannot well be included in an average. In the remaining case the rat developed a labyrinth disorder occasionally observed in this strain.

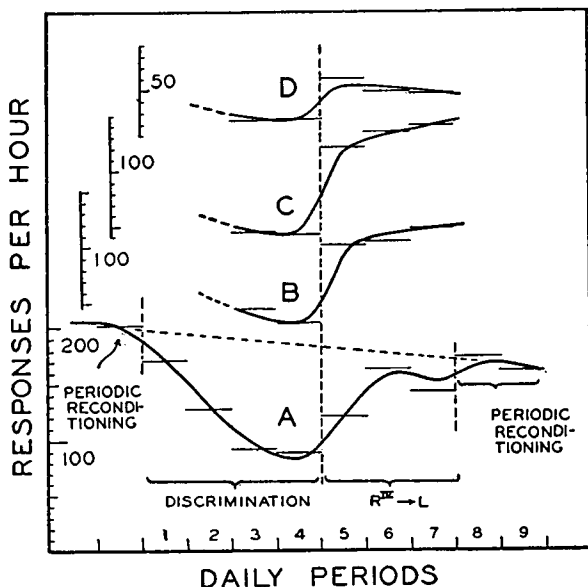


FIGURE 1.

A. The average rate of responding for seven rats, established at a value of about 200 responses per hour under periodic reconditioning, falls during four daily hours of discrimination to less than 100 responses per hour. When undifferentiated responses begin to produce the differentiating stimulus (*L*), the rate rises (Days 5, 6, and 7), but to a value somewhat lower than that observed upon returning to the original procedure of periodic reconditioning in the continued absence of *L* (days 8 and 9).

B.C.D. Averages for groups of eight, four, and four rats, respectively, showing the last two days of a discrimination* and three days on which undifferentiated responses produce the differentiating stimulus.

This is shown in Curve *A*, Figure 1, which gives the average for the seven completed series. In this figure no attempt is made to follow the rate during each hour. The rates have been plotted as horizontal bars as if they were constant. In order to indicate the course of the change from day to day, smoothed curves have been drawn to the center of these bars. It will be seen from this figure that the average rate of responding falls during discrimination from 202 responses per hour at the beginning of the first day to 89 per hour on the fourth day. On the fifth day, when responses to $S_{AB}..$

now produce the differentiating stimulus periodically, the rate increases to 121 on the first day and to 163 on the second. The rate drops to 143 on the third day, indicating that 163 may be a compensation for the low value of 121 on the first day.

The average for the three days is 142, significantly below the previous rate of 201 for periodic reconditioning. We expect some decline in this rate with time (2) but by returning to the procedure of periodic reconditioning it can be shown that the periodic rate has not fully been attained. Thus, on the eighth day L was omitted altogether; periodically responses to S_{AB} now produced, not L , but D . The resulting rates on two successive days are 173 and 161 or an average of 167, which still shows a (more reasonable) decline in rate during the 16 or 18 (chronological) days of the experiment. The difference between 142 and 167 is, however, subject to a correction that will be made in the Appendix.

Another group of eight rats approximately 160 days old had been through a very extensive series of reversed discriminations in which the extra stimulus was a light, but in which the actual differentiation had come to be based upon neither the presence nor the absence of the light but the change from one to the other in either direction (7). The average rates on the last two days of the series were 96 and 83 respectively. The rate was not falling as rapidly as this single difference would indicate. The procedure was then changed so that responses in the dark periodically produced the light, after which a response was reinforced. The increase in rate was in this case practically complete on the first day, as shown in Figure 1, Curve B . No recent periodic rates were available for comparison, nor was the procedure changed to periodic reconditioning with this group.

A third group of four rats approximately 170 days old had established a discrimination to the light without previous periodic reconditioning, the data for which have been reported (7). On the third and fourth days the average rates were 44 and 42 respectively. On establishing the relation of S_{AB} to L the rate increased to 120, 133, and 139 responses per hour, as shown in Curve C , Figure 1.

A fourth group of four rats, approximately 150 days old, had established a discrimination without previous conditioning (5), in which the differentiating component was the *absence* of a light. On the

fifth and sixth days of the discrimination, the average rates were 24 and 25 responses per hour respectively, the slight increase being insignificant. Upon changing the procedure (so that periodically a response in the presence of the light resulted in its disappearance and the next response was reinforced) the rate increased to 61 responses per hour, dropping to 50 and 49 on the following days. The unusually low values for these animals and the relatively slight increase are partly due to the method of discrimination, but another important factor is described in the Appendix.

The important point in such a series is the first day of the relation of R^V and L . To express the matter in the vernacular: "the rat is in the course of learning to press the lever only when L is present; it must now learn that it is itself producing L ." The result appears in the present analysis as a change from the low value of $(S_{AB}-R)$ obtaining under the partially completed discrimination to that obtaining under periodic reinforcement by the differentiating stimulus. It is clear from our data for the first day that the change begins very soon, but we need to turn to the daily records themselves for its actual course. These records are obtained automatically in the form of number-time graphs. We are interested in any increase shown on the day of the change over the rate that would be expected from the continuation of the discrimination. The latter could be calculated by extrapolation from the preceding part of the curve, but for our present purposes we may suppose that the rate to be expected on the day of the change is identical with that of the preceding day. Any error introduced by this assumption works against the argument of the paper. If we subtract this expected rate from the rate actually observed, any increase as the effect of L will be clearly shown. In practice, measurements of the height of the curves were made at intervals of ten minutes during the hour. Averages of these points on the last days of the discrimination were subtracted from those for the first days of the change. The results are given in Figure 2. Here the base line is in each case the average summation curve for the responses of the group on the preceding day. The curves show the increases above this base line as the result of reinforcement by L .

It is obvious that the effect is immediately felt. In all four groups a significant increase is evident at the end of ten minutes,

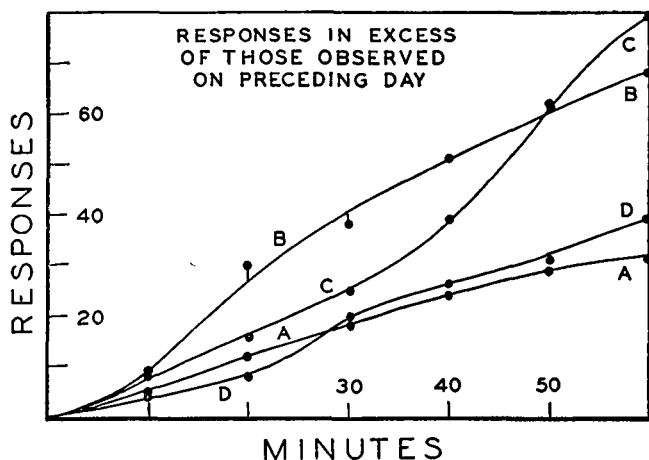


FIGURE 2.

Data for the groups in Figure 1, showing increases on the first day of the change over the responses observed on the last day of the discrimination (Day 5 in Figure 1 minus Day 4).

when only two reinforcements have occurred. In Group A this increase represents very nearly the full value: successive periods each add about the same number of responses. It should be noted, however, from Figure 1, that the average value for this group for the first day of the change is low, and that a further increase in rate occurs on the following day. In the other three groups a significant increase is apparent, but it is followed sooner or later by a more marked acceleration. In Group B the greatest increase is observed between 10 and 20 minutes after the beginning of the hour; in Group C between 40 and 50 minutes; and in Group D between 20 and 30 minutes. These differences probably reflect the various histories of the four groups. Group A began with some periodic reconditioning and its only discrimination had not been carried very far. Group B had a very thoroughly established discrimination. Group C had had no previous periodic reconditioning, which may account for its delayed acceleration. There are special reasons for the low values in Group D, which will be noted in the Appendix. A typical series of actual records is reproduced in Figure 3.

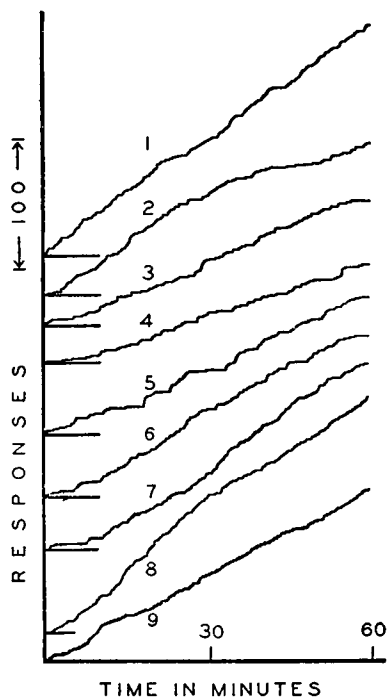


FIGURE 3

A typical series of daily records for one rat in Group *A*, Figures 1 and 2. In records 1, 2, 3, and 4 the rate declines during the establishment of the discrimination. In records 5, 6, and 7 responses in the absence of the differentiating stimulus periodically produce the stimulus and the rate rises. In records 8 and 9 there is a still further increase when the procedure is restored to that of periodic reconditioning. The increase is partly due to the fact that with this rat the differentiating stimulus was the *absence* of the sound of a buzzer; consequently the buzzer was present almost continuously on Days 5, 6, and 7, and significantly depressed the rate (see Appendix).

These four experiments show, without exception, that the production of a differentiating stimulus has a marked reinforcing effect and that this is felt immediately. It is not possible, however, to estimate the value of the effect very closely from the present experiment. It is probably of the same order as the effect of the sound of the magazine, but a mere comparison of the two periodic rates will not yield a fair estimate for the following reasons:

1. Since L is produced simultaneously with R^{IV} and since R^{III} follows immediately (within two seconds), S_D follows R^{IV} closely enough to have a considerable reinforcing effect upon it. Under the conditions indicated by " $R^{IV} \rightarrow L$ " it can be said that once every five minutes a response to $S_{AB.}$ is followed within two seconds by S_D^{II} (no attention being paid to the intervening events: $R^{IV} \rightarrow S^{IV} - R^{II}$). As shown elsewhere (8), an interval of two seconds between a response and the reinforcing stimulus reduces the effect of the reinforcement by not more than about 30 per cent. Consequently part of the periodic rate developed under " $R^{IV} \rightarrow L$ " may be due not to L but to D .

2. We also do not know whether the rate remaining as part of the discrimination must be supposed to be added to the periodic rate under " $R^{IV} \rightarrow L$." We do not know whether "pressing the lever in order to turn on the light" is the *same reflex* as "pressing the lever in order to make the magazine sound." If we must regard them as discrete entities, their separate rates of elicitation must be supposed to summate in our records. If the presentation of L has a reinforcing effect equal to that of D , [$S^{IV} - R^{IV}$] should on its own account reach a value nearly equal to that observed at the beginning of the experiment. But [$S^{III} - R^{III}$] is by no means near zero and, on the assumption that separate reflexes are involved, the total observed rate should be greater than that originally observed for [$S^{III} - R^{III}$] alone. This is not in agreement with our result but the assumption is not thereby ruled out. It may be that the effect of L is even less than we had supposed.

It is simpler, however, to regard ($S_{AB.}^{III} - R^{III}$) and ($S_{AB.}^{IV} - R^{IV}$) as the same reflex. We thereby avoid the systematic question of how to distinguish them if they are not, and we may easily account for the present data. The return to a higher rate is comparable with that observed during the abolishment of a discrimination through reinforcement of the previously extinguished member (4, Figure 2), where we do not expect summation. Under this interpretation we may say that the summed effect of L upon ($S^{IV} - R^{IV}$), of D upon ($S^{IV} - R^{IV}$), and of D upon ($S_{AB.}^{III} - R^{III}$), through induction from ($S_{AB.}^{III} - L - R^{III}$) is approximately equal to that of D upon ($S_{AB.}^{III} - R^{III}$) directly under periodic reconditioning. But this does not make possible a close estimate of the effect of L alone.

The experiment throws some light on a technical problem connected with discriminations in general. Where a differentiating stimulus is repeatedly presented to the organism, its occasional effect as a reinforcing stimulus must be taken into account. In the present method, if a light is presented every five minutes as a differentiating stimulus, it will have an added effect upon the rate whenever its presentation coincides with the elicitation of a response. In all experiments up to the present (with the exception of Group A in this paper) the differentiating stimulus has been set by hand, and the practice has been followed of waiting until the rat is not responding very rapidly. In this way coincidences have generally been avoided. However, in any close analysis of the discrimination curve, a possible undesired result of this procedure must be considered. Only responses following a short period of no-responding are ever reinforced; consequently a discrimination may be developed that will have for its effect the elimination of closely grouped responses. Although it is probable, as will be shown in a later paper, that no effect on the average rate will be felt, the procedure cannot be regarded as without some special effect. In Group A in this paper the entire experiment was conducted automatically. The differentiating stimulus was introduced periodically by a clock, and of course without respect to the momentary behavior of the rat. The discrimination curves do not differ significantly from those obtained with other methods, so far as the present degree of approximation is concerned, but in a closer examination the present result shows quite definitely that allowance must be made for an occasional coincidence.

APPENDIX

It will be convenient to report here some experiments on a separate point which were performed with the same animals and have some bearing upon the foregoing conclusions. A significant difference has previously been reported between a discrimination in which *L* is the *presence* of a stimulus and one in which it is the *absence*. Where *L* is a light, it has been shown that its presence depresses the rate of elicitation (7). If the initial periodic reconditioning occurs in the absence of the light, the introduction of the differentiating stimulus will cause a sudden drop in rate where the absence of the light is the differentiating stimulus, because during the in-

tervening periods of responding to $S_{AB..L..}$ (now the unreinforced member) the light is on. In Group A in the present experiments a control was introduced against the possibility that a discrimination in which L was the sound of a buzzer differed from one in which L was the absence of the sound. In one-half of the cases the discrimination was really the reverse of that described, although this was not mentioned at the time to avoid confusion. Of the successful series L was the *presence* of the buzzer in three cases. In the other four cases the buzzer was absent during the periodic reconditioning only and was therefore present most of the time. The curves of this group have been separated into two parts on this basis in Figure 4A. The resulting groups are small but give some indication of a difference. The horizontal solid lines are for the three rats

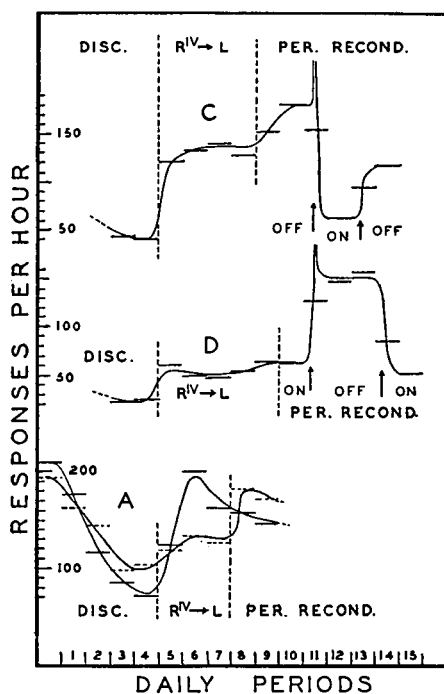


FIGURE 4.

Curves showing the depressive effect of the stimuli used for differentiation. Explanation in text.

with which $S_{AB.L.}$ was the lever plus the buzzer. The broken lines are for the others. There is no depressive effect on the rate during the discrimination but the process is *retarded*; the decline in rate is slower for the group in which the differentiation is the removal of the sound of the buzzer. When the relation between R^{IV} and L is established, a much more significant difference is to be seen. Where the rat is normally in silence but produces the sound of the buzzer periodically, the effect of the reinforcement is great. When the buzzer is sounding continuously, except when it is momentarily silenced by a response of the rat, the effect of the reinforcement is slight. Upon changing to simple periodic reconditioning the buzzers are silenced entirely, and the depressed group responds with a very significant increase in rate. Because of the low values for these four rats on Days 5, 6, or 7 it is impossible to compare the average rate for the group with the rate on Days 8 and 9 under periodic reconditioning.

In Group B all eight cases were as described, so that the present problem does not arise. In Group C the differentiating stimulus was the presence of a light; in D, its absence. These experiments correspond very well with those in Group A, Group D showing only a slight increase when the relation of R^{IV} and L is established. Groups C and D were subsequently tested directly for the effect of the light, which was found to be relatively great. The completed series for both are given in Figure 4. In the case of Group C (top curve in Figure 4) the return to periodic reconditioning (ninth day) yielded a probably significant increase over the previous rate under reinforcement from L . This group is homogeneous and constitutes the only very clear evidence in the experiment that the chain

$$S^{III}-R^{III} \dots \text{etc.}$$

is elicited somewhat more rapidly than

$$S^{IV}-R^{IV} \dots \text{etc.}$$

During this simple periodic reinforcement the light was off. On the 11th day it was turned on continuously beginning at 25 minutes. No other condition was changed. Since the light is at this point still a differentiating stimulus, and since responses in the presence of the light are now no longer reinforced, except periodically, an extinction curve follows. A typical record is shown in Figure 5,

Curve *C*. The convexity at the beginning of this curve is of the sort that can be expected as an incidental effect under periodic reconditioning. The horizontal line through the curve marks the beginning of the extinction curve for ($S_{AB.L.} - R$). The curve falls rapidly as the depressive effect of the light emerges over its excitatory character as a differentiating stimulus. The average rate for this day, including the extinction curve, is already lower than that

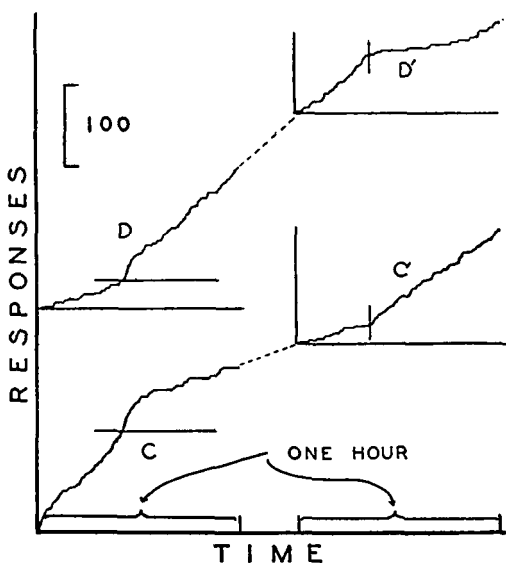


FIGURE 5.

Typical daily records showing the depressive effect of a light. Curve *C* shows the beginning of a record for periodic reconditioning in the absence of the light. At the horizontal line the light is turned on. Its first effect is as a differentiating stimulus, yielding the extinction curve for ($S_{AB.L.} - R$). The depressive effect emerges, however, and the final periodic slope (now in the presence of the light) is much less than that at the beginning. Curve *C'* is for the same rat on the second day following. It begins at the depressed slope. At the vertical bar the light is turned off, and the rate immediately changes to a higher value.

In the case of curve *D* the *absence* of the light is the differentiating stimulus. The record begins with the light on; its removal results in an extinction curve, as in *C*, but the subsequent rate shows an increase due to the removal of the depressing stimulus. Record *D'* is for the third day following. At the beginning the light is off; at the bar it is turned on, and the rate immediately falls.

of the previous day, and on the following day an unusually low value is maintained (record omitted in Figure 5). On the next day the light is turned off after twenty minutes. The rate again rises, although, for a reason that is not clear, it does not quite return to its former high value. In Figure 5, Curve *C'*, the vertical bar marks the change to "light off." The average for the group, plotted again as rate rather than as number vs. time, is given in Figure 4.

An important characteristic of the record *C'* in Figure 5 is the complete absence of any compensatory increase in rate following removal of the depressive stimulus. The depression is clearly different from cases previously reported where any tendency to suppress the rate is followed by marked compensation.

In the case of Group D (middle curve in Figure 4) the light is on during the simple periodic reconditioning (tenth day on the graph), and the rate shows no increase as the result of changing from R^{IV} —*L*. On the following day it is turned off after 25 minutes. An extinction curve follows for the same reason as in the case of Group C. Here, however, it leads to a greatly increased rate, a typical example of which is given in Figure 5, curve *D*. After two days of this rate, (omitted in Figure 5) the light is again turned on and the rate falls to its previous low level. In the particular case of curve *D'* (Figure 5) the effect is especially great immediately after the light is presented (at the vertical bar). Some slight recovery is evident toward the end of the hour.

SUMMARY

A discrimination is set up in which a response to a lever is elicited practically only when a differentiating stimulus (*L*) is present. An occasional response in the absence of *L* is then arranged to produce the appearance of *L* periodically. This has the effect of reconditioning the response in the absence of *L*. The rate of change is examined through its effect upon the rate of elicitation observed under periodic reconditioning. The change is found to begin immediately. Some later acceleration is usually observed.

A related experiment demonstrates that a differentiating stimulus such as a buzz or light may have a marked depressive effect upon the rate of elicitation during periodic reconditioning.

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L'EFFET RENFORÇANT D'UN STIMULUS DIFFÉRENCIANT

(Résumé)

Une discrimination est établie où une réponse à un levier ne se montre presque que quand un stimulus différenciant (*L*) est présent. Une réponse occasionnelle en l'absence de *L* est ensuite faite pour produire l'apparence de *L*. Ceci a l'effet de rendre la réponse de nouveau conditionnelle en l'absence de *L*. On examine la vitesse du changement dans son effet sur la vitesse de la mise en action observée dans le réconditionnement périodique. On constate que le changement commence immédiatement. On note ordinairement quelque accélération plus tard.

Une expérience ayant rapport à celle-ci montre qu'un stimulus différenciant tel qu'une sonnette bourdonnante ou une lumière peut avoir un effet dépressif sur la vitesse de la mise en action pendant le réconditionnement périodique.

SKINNER

DIE VERSTÄRKUNGSWIRKUNG DES DIFFERENZIRENDEN

REIZES

(Referat)

Eine Unterscheidungsaufgabe wurde gegeben, in der eine Antwort mit einem Hebel nur dann gemacht wurde, wenn ein differenzierender Reiz (*L*) vorhanden sei. Eine gelegentliche Antwort bei der Abwesenheit von *L* wird dann so gemacht, dass er *L* erzeugt. Dies hat als Folge die Wieder-

bedingung der Antwort in der Abwesenheit von *L*. Die Schnelligkeit der Veränderung wird unter periodischer Wiederbedingung beobachtet. Es wurde festgestellt, dass die Veränderung sofort einsetzt. Einige spätere Beschleunigung wird gewöhnlich bemerkt.

Ein ähnliches Experiment beweist, dass ein differenzierender Reiz, wie ein Summen oder ein Licht eine ausgesprochene depressive Wirkung auf die Schnelligkeit der Hervorrufung während der periodischer Wiederbedingung haben mag.

SKINNER